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Date of Filing	:	10 DEC 2003
Application Number	:	200307531-4
Applicant(s) / Proprietor(s) of Patent	:	AGENCY FOR SCIENCE, TECHNOLOGY AND RESEARCH
Title of Invention	:	METHOD AND APPARATUS FOR BINARISING IMAGES

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

Chig Kam Tack (Mr)
Senior Assistant Registrar
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SINGAPORE

17 Dec 2004

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PATENTS FORM 1
Patents Act
(Cap. 221)
Patents Rules
Rule 19

INTELLECTUAL PROPERTY OFFICE OF SINGAPORE

REQUEST FOR THE GRANT OF A PATENT UNDER SECTION 25

* denotes mandatory fields

1. YOUR REFERENCE* SP5911

2. TITLE OF INVENTION* METHOD AND APPARATUS FOR BINARISING IMAGES

3. DETAILS OF APPLICANT(S)* (see note 3) Number of applicant(s) 1

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Country: SG

[X] For corporate applicant

[ ] For individual applicant

State of incorporation:

State of residency:

Country of incorporation: SG

Country of residency:

[ ] For others (please specify in the box provided below)

(B) Name:

Address:

State:

Country:

For corporate applicant

State of incorporation

Country of incorporation

For individual applicant

State of residency

Country of residency

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For corporate applicant

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For individual applicant

State of residency

Country of residency

For others (please specify in the box provided below)

Further applicants are to be indicated on continuation sheet 1

4. DECLARATION OF PRIORITY (see note 5)

A. Country/country designated

File number

Filing Date DD MM YYYY

B. Country/country designated

File number

Filing Date DD MM YYYY

Further details are to be indicated on continuation sheet 6

5. INVENTOR(S)* (see note 6)

A. The applicant(s) is/are the sole/joint inventor(s) Yes No X

B. A statement on Patents Form 8 is/will be furnished Yes [X] No [ ]

6. CLAIMING AN EARLIER FILING DATE UNDER (see note 7)

[ ] section 20(3) [ ] section 26(6) [ ] section 47(4)

Patent application number [ ]

DD MM YYYY

Filing Date [ ]

Please mark with a cross in the relevant checkbox provided below
(Note: Only one checkbox may be crossed.)

[ ] Proceedings under rule 27(1)(a)

DD MM YYYY

Date on which the earlier application was amended [ ]

[ ] Proceedings under rule 27(1)(b)

7. SECTION 14(4)(C) REQUIREMENTS (see note 8)

Invention has been displayed at an international exhibition. Yes [ ] No [X]

8. SECTION 114 REQUIREMENTS (see note 9)

The invention relates to and/or used a micro-organism deposited for the purposes of disclosure in accordance with section 114 with a depository authority under the Budapest Treaty.

Yes [ ] No [X]

9. CHECKLIST*

(A) The application consists of the following number of sheets

i.	Request	5	Sheets
ii.	Description	10	Sheets
iii.	Claim(s)	4	Sheets
iv.	Drawing(s)	3	Sheets
v.	Abstract (Note: The figure of the drawing, if any, should accompany the abstract)	1	Sheets
Total number of sheets		23	Sheets

(B) The application as filed is accompanied by:

[ ] Priority document(s) [ ] Translation of priority document(s)

Statement of inventorship & right to grant

International exhibition certificate

10. DETAILS OF AGENT (see notes 10, 11 and 12)

Name	
Firm	LLOYD WISE

11. ADDRESS FOR SERVICE IN SINGAPORE* (see note 10)

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Street Name	P.O BOX 636				
Building Name	TANJONG PAGAR POST OFFICE				
Postal Code	910816				

12. NAME, SIGNATURE AND DECLARATION (WHERE APPROPRIATE) OF APPLICANT OR AGENT* (see note 12)
(Note: Please cross the box below where appropriate.)

X I, the undersigned, do hereby declare that I have been duly authorised to act as representative, for the purposes of this application, on behalf of the applicant(s) named in paragraph 3 herein.

Lloyd Wise

Name and Signature LLOYD WISE

DD MM YYYY
10 12 2003

Our Ref: SP5911

NOTES:

1. This form when completed, should be brought or sent to the Registry of Patents together with the rest of the application. Please note that the filing fee should be furnished within the period prescribed.

2. The relevant checkboxes as indicated in bold should be marked with a cross where applicable.

3. Enter the name and address of each applicant in the spaces provided in paragraph 3.
   Where the applicant is an individual
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   -The address of each individual should also be furnished in the space provided.
   - The checkbox for "For individual applicant" should be marked with a cross.

   Where the applicant is a body corporate
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   - The address of the body corporate should also be furnished in the space provided.
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   - The details of all partners must be provided. The name of each partner should be indicated in full and the surname or family name should be underlined.
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5. The declaration of priority in paragraph 4 should state the date of the previous filing, the country in which it was made, and indicate the file number, if available. Where the application relied upon in an International Application or a regional patent application e.g. European patent application, one of the countries designated in that application [being one falling under section 17 of the Patents Act] should be identified and the country should be entered in the space provided.

6. Where the applicant or applicants is/are the sole inventor or the joint inventors, paragraph 5 should be completed by marking with a cross the 'YES' checkbox in the declaration (A) and the 'NO' checkbox in the alternative statement (B). Where this is not the case, the 'NO' checkbox in declaration (A) should be marked with a cross and a statement will be required to be filed on Patents Form 8.

7. When an application is made by virtue of section 20(3), 26(6) or 47(4), the appropriate section should be identified in paragraph 6 and the number of the earlier application or any patent granted thereon identified. Applicants proceeding under section 26(6) should identify which provision in rule 27 they are proceeding under. If the applicants are proceeding under rule 27(1)(a), they should also indicate the date on which the earlier application was amended.

8. Where the applicant wishes an earlier disclosure of the invention by him at an International Exhibition to be disregarded in accordance with section 14(4)(c), then the 'YES' checkbox at paragraph 7 should be marked with a cross. Otherwise, the 'NO' checkbox should be marked with a cross.

9. Where in disclosing the invention the application refers to one or more micro-organisms deposited with a depository authority under the Budapest Treaty, then the 'YES' checkbox at paragraph 8 should be marked with a cross. Otherwise, the 'NO' checkbox should be marked with a cross. Attention is also drawn to the Fourth Schedule of the Patents Rules.

10. Where an agent is appointed, the fields for "DETAILS OF AGENT" and "ADDRESS FOR SERVICE IN SINGAPORE" should be completed and they should be the same as those found in the corresponding Patents Form 41. In the event where no agent is appointed, the field for "ADDRESS FOR SERVICE IN SINGAPORE" should be completed, leaving the field for "DETAILS OF AGENT" blank.

11. In the event where an individual is appointed as an agent, the sub-field "Name" under "DETAILS OF AGENT" must be completed by entering the full name of the individual. The sub-field "Firm" may be left blank. In the event where a partnership/body corporate is appointed as an agent, the sub-field "Firm" under "DETAILS OF AGENT" must be completed by entering the name of the partnership/body corporate. The sub-field "Name" may be left blank.

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13. Applicants resident in Singapore are reminded that if the Registry of Patents considers that an application contains information the publication of which might be prejudicial to the defence of Singapore or the safety of the public, it may prohibit or restrict its publication or communication. Any person resident in Singapore and wishing to apply for patent protection in other countries must first obtain permission from the Singapore Registry of Patents unless they have already applied for a patent for the same invention in Singapore. In the latter case, no application should be made overseas until at least 2 months after the application has been filed in Singapore, and unless no directions had been issued under section 33 by the Registrar or such directions have been revoked. Attention is drawn to sections 33 and 34 of the Patents Act.

14. If the space provided in the patents form is not enough, the additional information should be entered in the relevant continuation sheet. Please note that the continuation sheets need not be filed with the Registry of Patents if they are not used.

1. SP591101.doc

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Methods and apparatus for binarising images

Field of the invention

The present invention relates to methods for processing an image so as to classify pixels of the image based on an intensity threshold. In particular, the invention relates to such a method having an improved process for selection of the threshold. The invention is applicable to both medical and non-medical images.

Background of Invention

Binarisation is a well-known technique for image segmentation - that is classifying pixels of the image into two classes. Binarisation performs this classification based on whether a given pixel of the image has an intensity (gray-level) above or below a threshold. Binarisation has been widely applied to a number of image processing and computer vision applications, as a preliminary segmentation step. It makes an implicit assumption that an object of interest in the image has different intensity values from other (background) portions of the image.

Many techniques exist for selection of the threshold. For example, in some such processes, the threshold can be selected in a process involving user interaction, while in other processes the threshold is selected entirely automatically. In some such processes the threshold is selected locally (i.e. such that the threshold varies from one pixel to another), while in other processes the threshold is the same over the whole image.

Most automatic threshold selection methods employ a histogram of the gray levels in the image. For example, Otsu [1] proposed a selection of the threshold to maximise the separability of the resultant classes in gray levels,

which is performed by minimising the within-class variance. Li and Lee [2] selected the threshold by minimising the cross entropy between the image and its segmented version. Kittler and Illingworth [3] selected the threshold by minimising the Bayes errors under the assumption that the object and pixel gray level values are normally distributed. Kapur et al [4] provided a maximum entropy approach. Wong and Sahoo [5] maximised the entropy with constraints on the region homogeneity and object boundary. Saha and Udupa [6] proposed a technique which maximised class uncertainty and homogeneity of the regions. Cheng et al [7] used the concept of fuzzy c-partition and the maximum fuzzy entropy principle to select a threshold.

Cheung at al (US5,231,580A, 1993) disclosed an automatic method to characterise nerve fibres using local thresholds. It first partitions the entire image into sub-images and finds the threshold for each sub-image using a histogram-based thresholding method. Then, the pixel-wise threshold is approximated by interpolating the thresholds of neighbouring subimages.

Summary of the Invention

It is observed that the existing methods for selecting a threshold described above lack a mechanism for incorporating prior knowledge about the images to be binarised.

Thus, the present invention aims to provide a new and useful technique for selecting a threshold for binarising an image, and in particular one which enables prior knowledge to be explicitly incorporated.

In general terms, the invention proposes firstly that this prior knowledge is used to define a region of interest (ROI) in the image, such that the analysis of frequency distribution of pixel intensities (represented by a frequency histogram) is performed only for pixels in the ROI. Secondly, the invention

proposes that the prior knowledge is used to select an intensity range, and that only pixels within this intensity range are used to generate the frequency distribution from which the threshold is selected.

These two ideas are in principle separate, but in combination they provide a highly effective mechanism for incorporating prior knowledge into the threshold selection. The advantage is critical whether the image is a medical one or not. In particular, a threshold can be found to binarise images which exhibits high robustness to imaging artefacts such as gray level inhomogeneity and noise.

Specifically, one expression of the invention is a method of binarising an image composed of pixels having respective intensity values, the method comprising:

(i) using prior knowledge about the image to derive a region of interest within it;

(ii) using prior knowledge about the image to derive an intensity range of pixels in the said region of interest;

(iii) obtaining a frequency distribution of the intensities within the said intensity range of pixels within the said region of interest;

(iv) using the said frequency distribution to derive an intensity threshold; and

(v) binarising the image by classifying pixels in the said region of interest according to whether their intensities are above or below the said intensity threshold.

The invention may alternatively be expressed as a computer system which is set up to perform such a method. Alternatively, it can be expressed as software for performing the method.

Brief Description of The Figures

Preferred features of the invention will now be described, for the sake of illustration only, with reference to the following figures in which:

Fig. 1 shows the steps in a method which is an embodiment of the invention;

Fig. 2 shows an MR SPGR intercommissural axial slice of a brain, which is a suitable subject for the method of Fig. 1;

Fig. 3 shows a region of interest within the image of Fig. 2 derived by a first step of the method of Fig. 1;

Fig. 4 is a gray-level histogram of the ROI shown in Fig. 3, and a threshold selected in one form of a step of the method of Fig. 1; and

Fig. 5 shows the binarised image using the threshold selected in the method of Fig. 1.

Detailed Description of the embodiments

Referring firstly to Fig. 1, the overall steps of a method which is an embodiment of the invention are shown.

In step 1, an image is input.

In step 2, prior knowledge of the image is used to define a region of interest (ROI) which is a subset of the image. This process can be done by whatever means, either automatic, semi-automatic, or even manual.

In step 3 an analysis is performed on the frequency of occurrence of intensities within the ROI, and a range of frequencies is defined, again using prior knowledge.

For example, without losing generality, we denote the image to be processed as *f(x)*, where *f(x)* is the gray level at a pixel labelled *x*. It is further supposed that the processed image has L gray levels denoted by r_i where *i* is an integer in the range 0 to *L-1* and $r_0 < r_1 < \ldots r_{L-1}$. It is also assumed that the object of interest has higher intensity values than the background. Suppose that due to prior knowledge or test we know that the proportion of the region of interest which is occupied by the object is in the percentage range per_0 to per_1.

Let *h(i)* denote the frequency of gray level r_i, and let *H(i)* denote the cumulative frequency which is $\sum_{i'=0}^{i} h(i')$, where *i'* is an integer dummy index. Considering two values of *i* written as *m* and *n*, the frequency of intensities in the range r_m to r_n *is* $\sum_{i'=m}^{n} h(i')$. Thus, we can use per_0 to calculate a gray level r_{low}, such that we are sure that all the pixels having lower intensity represent background. r_{low} can be written as:

$$r_{low} = \min_i \{ i \mid H(i) \geq per_0 \}. \quad (1)$$

Similarly, we can use per_1 to calculate a gray level r_{high} such that we are sure that all pixels having higher intensity represent the object:

$$r_{high} = \min_i \{ i \mid H(i) \geq per_1 \}. \quad (2)$$

In a step 4 of the method of Fig 1, the threshold is selected using an algorithm which operates on the frequencies within the selected range from r_{low} to r_{high}. The details of several ways in which this can be carried out within the scope

of the invention are given below. Thus, a selected threshold is output in step 5.

Image binarisation is then performed using this threshold, to create an image in which all pixels (at least in the ROI) are classified into two classes. Further image processing steps may optionally be performed at this stage.

We now turn to a discussion of three techniques by which step 4 can be carried out.

1. Range-constrained least valley detection method (RCLVD)

If the frequency range derived in step 3 is correctly estimated then it will include a valley in the frequency distribution of intensities. This valley separates the background and the object. Thus, valley detection can be exploited to select the threshold. This has the following steps:

1) A frequency interval δh is specified.

2) The gray level range $[r_{low}, r_{high}]$ is partitioned into K+1 intervals with an equal frequency range δh. For an interval labelled by integer index j, the lower end of its intensity range is denoted r_1^j and the upper end is denoted r_2^j. Thus:

$$r_1^0 = r_{low},\ r_2^0 = \min_i\{i \mid H(i) \geq (per_0 + \delta h)\},$$

$$r_1^1 = r_2^0,\ r_2^1 = \min_i\{i \mid H(i) \geq (H(r_1^1) + \delta h)\},$$

...

$$r_1^K = r_2^{K-1},\ r_2^K = \min_i\{i \mid H(i) \geq (H(r_1^K) + \delta h)\ .$$

$H(r_1^K + \delta h) \geq per_1$ and $H(r_1^K) < per_1$.

3) The average frequency $\bar{h}^j$ for each of the intervals j *is calculated* given by

$$\bar{h}^J = (H(r_2^J) - H(r_1^J))/(r_2^J - r_1^J)$$

4) Let J denote the interval for which $\bar{h}^J$ is a minimum. The threshold of this RCVLD method, which is denoted θ_{RCVLD}, may be selected to be any value in the range r_1^J to r_2^J, such as $\theta_{RCVLD} = (r_2^J + r_1^J)/2$.

2. Range-constrained weighted variance method (RCWV)

Let r_k fall within the range r_{low} to r_{high}, and suppose that the pixels of the ROI are in two classes C_1 and C_2, where C_1 is pixels of the background class and consists of pixels with gray levels r_{low} to r_k, and C_2 is pixels of the object class and is composed of pixels with gray levels r_k+1 to r_{high}. The range-constrained weighted variance method maximises the "weighted between-class variance" defined as:

$$\theta_{RCWV}(W_1, W_2) = \max_{r_k}(\Pr(C_1)D(C_1)W_1 + \Pr(C_2)D(C_2)W_2),$$

where W_1 and W_2 are two positive constants selected by the user and representing the weights of the two respective class variances, $Pr(.)$ denotes the class probability, i.e.

$$\Pr(C_1) = \sum_{i=r_{low}}^{r_k} h(i),\ \Pr(C_2) = \sum_{i=r_k+1}^{r_{high}} h(i),$$

and $D(C_1)$ and $D(C_2)$ are given by:

$D(C_1) = (\mu_0 - \mu_T)^2$ and $D(C_2) = (\mu_1 - \mu_T)^2$, where $\mu_T = \sum_{i=r_{low}}^{r_{high}} i \times h(i)$,

$\mu_0 = \sum_{i=r_{low}}^{r_k} i \times h(i)$ and $\mu_1 = \sum_{i=r_k+1}^{r_{high}} i \times h(i)$.

When W_1 is bigger than W_2, background homogeneity is emphasised.

3. Range-constrained fuzzy c-partition thresholding method (RCFCP)

This third method is related to the technique used in [7], and the justification for it is as given there. In general terms, let A_b / A_0 be the fuzzy sets of fuzzy events "background/object" (which denotes a fuzzy partition of the set $\{r_{low},\ldots,r_{high}$ with a membership function μ_{A_b} / μ_{A_0} respectively). The probability of these fuzzy events are given by:

$P(A_i) = \sum_{j=r_{low}}^{r_{high}} \mu_{A_i}(j) \times h_j$, where $A_i \in \{A_b, A_0\}$, and the weighted entropy with this fuzzy partition can be calculated as:

$$S(W_1,W_2) = W_1 \times P(A_b) \times \log P(A_b) + W_2 \times P(A_0) \times \log P(A_0)$$

where W_1 and W_2 are two positive constants, and *log(.)* is the natural logarithm.

Let $r_{low} \le a < c \le r_{high}$. The membership functions can be defined as follows:

$$\mu_{A_b}(x) = \begin{cases} 1, & r_{low} \le x \le a \\ (x-c)/(a-c) & a < x < c \\ 0 & c < x \le r_{high} \end{cases}$$

and

$$\mu_{A_0}(x) = \begin{cases} 1, & r_{low} \le x \le a \\ (x-a)/(c-a) & a < x < c \\ 0 & c < x \le r_{high} \end{cases}.$$

The optimum parameters a^* and c^* are chosen to maximise the entropy $S(W_1, W_2)$, and the optimum threshold is $\theta_{RCFCP} = (a^* + c^*)/2$.

Having now presented the steps of the embodiment in principle, we turn to an example of the embodiment in operation. This example uses the form of step 4 referred to above as RCLVD.

The starting point of the method is the image shown in Fig. 2, an MR (Magnetic Resonance) image which is a T1-weighted or SPGR (spoiled

gradient recalled acquisition) axial slice around the intercommissural plane. This image is input in step 1 of the method.

In step 2 of the method, we calculate the pixels enclosed by the skull (i.e. find the ROI) using the following steps: the usual histogram-based thresholding method is used to binarise the axial slice; a morphological closing operation is used to connect small gaps; the largest connected component is identified; and the holes within the component are filled. The resulting ROI (the pixels enclosed by the skull) is shown in Fig. 3.

In step 3, the two percentages per_0 and per_1 are set as 14% and 28%. This selection is based on previous experiments and/or other prior knowledge.

In step 4 of the method (RCLVD), we select the δh to be 1% (alternatively any value in the range 1% to 5% would be suitable). Fig. 4 shows the histogram of frequencies in the ROI, and the calculated threshold θ_{RCLVD} is shown as the line indicated. This completes the procedure of the embodiment.

The output threshold of the method is used as in conventional techniques to binarise the image. The binarised image is shown in Fig. 5.

Although only a single embodiment of the invention has been described, many variations are possible within the scope of the invention as will be clear to a skilled reader.

References

The disclosure of the following references is incorporated herein by reference in their entirety:

[1] Otsu N., "A threshold selection method from gray-level histograms", IEEE Transactions on Systems, Man and Cybernetics, 1979; 9: p62-66.

[2] Li C. H., Lee C. K., "Minimum cross entropy thresholding", Pattern Recognition 1993; 26: p617-625.

[3] Kittler J., Illingworth J., "Minimum error thresholding", Pattern Recognition 1986; 19: p41-47.

[4] Kapur J.N. , Sahoo P.K., Wong A.K.C., "A new method for gray-level picture thresholding using the entropy of the histogram", Computer Vision Graphics and Image Processing, 1985, 29; 273-285.

[5] Wong A.K. C. and Sahoo P.K., "A gray-levl threshold selection method based on maximum entropy principle", IEEE Transactions on Systems, Manand Cybernetics, 1989; 19: p866-871.

[6] Saha P.K. and Udupa J.K., "Optimum image thresholding via class uncertainty and region homogeneity", IEEE Transactions on Pattern Analysis and Machine Intelligence, 2001; 23: p689-706.

[7] Cheng H.D., Chen J., and Li J., "Threshold selection based on fuzzy c-partition entropy approach", Pattern Recognition 1998; 31: p857-870.

Claims

1. A method of binarising an image composed of pixels having respective intensity values, the method comprising:

(i) using prior knowledge about the image to derive a region of interest within it;

(ii) using prior knowledge about the image to derive an intensity range of pixels in the said region of interest;

(iii) obtaining a frequency distribution of the intensities within the said intensity range of pixels within the said region of interest;

(iv) using the said frequency distribution to derive an intensity threshold; and

(v) binarising the image by classifying pixels in the said region of interest according to whether their intensities are above or below the said intensity threshold.

2. A method according to claim 1 in which in step (iv), the threshold is found by deriving a valley in the frequency distribution within the range, and selecting the intensity threshold to correspond to the valley.

3. A method according to claim 2 in which the valley is found by determining the total intensities in a number of intervals defined in the range, and selecting the intensity threshold as an intensity within the interval having the lowest total intensity.

4. A method according to claim 3 in which the intensity threshold is selected as the mid-point of the interval having the lowest total intensity.

5. A method according to claim 1 in step (iv) the threshold is found by minimising a function which is a sum of the variances of the intensities below and above the threshold.

6. A method according to claim 5 in which the sum is a weighted sum defined based on two constants W_1 and W_2.

7. A method according to claim 6 in which, representing labelling the possible values of pixel intensity by an integer index i and their respective frequencies by $h(i)$, and writing the lower and upper intensities respectively as r_{low} and r_{high}, the weighted sum is given by

$$\theta_{RCWV}(W_1,W_2)=\max_{r_k}(\Pr(C_1)D(C_1)W_1+\Pr(C_2)D(C_2)W_2),$$

where $Pr(.)$ denotes the class probability ($\Pr(C_1)=\sum_{i=r_{low}}^{r_k}h(i)$ and $\Pr(C_2)=\sum_{i=r_k+1}^{r_{high}}h(i)$), and $D(C_1)$ and $D(C_2)$ are given by:

$D(C_1)=(\mu_0-\mu_T)^2$ and $D(C_2)=(\mu_1-\mu_T)^2$, where $\mu_T=\sum_{i=r_{low}}^{r_{high}}i\times h(i)$, $\mu_0=\sum_{i=r_{low}}^{r_k}i\times h(i)$ and $\mu_1=\sum_{i=r_k+1}^{r_{high}}i\times h(i)$.

8. A method according to claim 1 in which step (iv) is performed by selecting the threshold as a function of parameters which maximise an entropy function which indicates the entropy of a fuzzy partition of the pixels into classes based on the parameters.

9. A method of processing an image which includes binarising it by a thresholding method according to any preceding claim, and then modifying the classification of one or more of the pixels by considering spatial relationships between the locations of the classified pixels.

10. A computer program product comprising a recording medium and programming instructions stored on the recording medium and readable by a computer system to cause the computer system to perform a method according to any preceding claim.

11. A computer system for binarising an image composed of pixels having respective intensity values, the system including:

(i) at least one data input device for a user to select a region of interest in the image and specify a frequency range within the frequency distribution of the intensities of pixels in the region of interest;

(ii) a processor arranged to obtain a frequency distribution of the intensities within the intensity range of pixels within the region of interest, use the frequency distribution to derive an intensity threshold; and binarise the image by classifying pixels in the region of interest according to whether their intensities are above or below the threshold.

12. A system according to claim 11 in which the processor is arranged to derive the threshold by deriving a valley in the frequency distribution within the range, and selecting the intensity threshold to correspond to the valley.

13. A system according to claim 12 in which processor is arranged to find the valley by determining the total intensities in a number of intervals defined in the range, and selecting the intensity threshold as an intensity within the interval having the lowest total intensity.

14. A system according to claim 13 in which the processor is arranged to select the intensity threshold as the mid-point of the interval having the lowest total intensity.

15. A system according to claim 14 in which the processor is arranged to select the threshold by minimising a function which is a sum of the variances of the intensities below and above the threshold.

16. A system according to claim 15 in which the sum is a weighted sum defined based on two constants W_1 and W_2.

17. A system according to claim 16 in which, representing labelling the possible values of pixel intensity by an integer index *i* and their respective frequencies by *h(i)*, and writing the lower and upper intensities respectively as r_{low} and r_{high}, the weighted sum is given by

$$\theta_{RCLWV}(W_1, W_2) = \max_{r_k}(\Pr(C_1)D(C_1)W_1 + \Pr(C_2)D(C_2)W_2),$$

where *Pr(.)* denotes the class probability ($\Pr(C_1) = \sum_{i=r_{low}}^{r_k} h(i)$ and $\Pr(C_2) = \sum_{i=r_k+1}^{r_{high}} h(i)$),, and $D(C_1)$ and $D(C_2)$ are given by:

$D(C_1) = (\mu_0 - \mu_T)^2$ and $D(C_2) = (\mu_1 - \mu_T)^2$, where $\mu_T = \sum_{i=r_{low}}^{r_{high}} i \times h(i)$,

$\mu_0 = \sum_{i=r_{low}}^{r_k} i \times h(i)$ and $\mu_1 = \sum_{i=r_k+1}^{r_{high}} i \times h(i)$.

18. A system according to claim 11 in which the processor is arranged to select the threshold as a function of one or more parameters which maximise an entropy function which indicates the entropy of a fuzzy partition of the pixels into classes based on the parameters.

19. A system according to any of claims 11 to 18 in which the processor is further arranged to process the segmented image by modifying the classes to which each pixel is allocated by considering relationships between the locations of the pixels which have been classified.

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Abstract

Methods and apparatus for binarising images

A method is proposed for binarising an image by deriving an intensity threshold and classifying pixels according to whether their intensity is below or above the threshold. In the derivation of the threshold, prior knowledge is used to define a region of interest (ROI) in the image. Furthermore, prior knowledge is used to select a range in the frequency distribution of the intensities of the pixels in the ROI, and that only data within this frequency range is used to derive the threshold. These techniques provide a highly effective mechanism for incorporating prior knowledge into the threshold selection which is critical whether the image is a medical image or not. In particular, a threshold can be found to binarise images which exhibits high robustness to imaging artefacts such as gray level inhomogeneity and noise.

[Fig. 1]

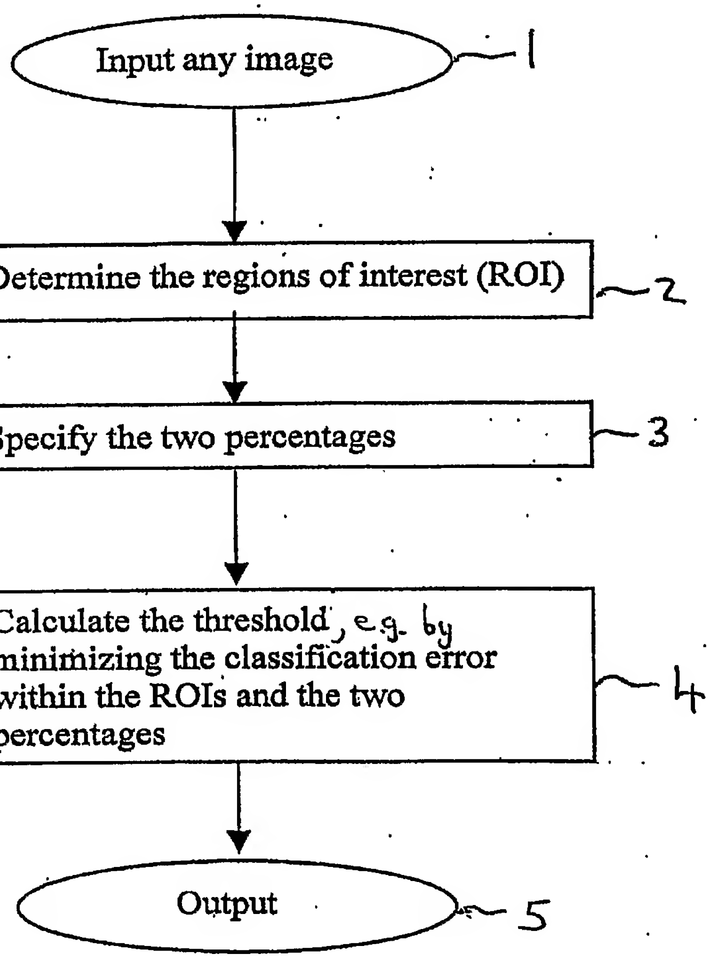
Input any image
1
Determine the regions of interest (ROI)
2
Specify the two percentages
3
Calculate the threshold, e.g. by minimizing the classification error within the ROIs and the two percentages
4
Output
5

Fig. 1

Figure 2.

Figure 3.

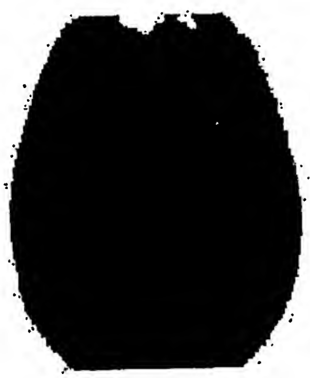

Figure 4. θ_{RCLVD}

Figure 5.